F/A-18 / AIM-132 ASRAAM
Integration, Test and Clearance Program

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ABSTRACT

In 1998 the Australia Government decided to acquire the UK AIM-132 ASRAAM as a replacement for the US AIM-9M Sidewinder currently in inventory for F/A-18 Hornet aircraft. Australian Defence Force (ADF) policy on the acquisition of new technical equipment is to perform Test and Evaluation (T&E) if an aircraft stores clearance or certification with sufficient testing has not already been carried out by recognised test agencies iaw MIL-HDBK-1763. The total T&E effort required to integrate this weapon onto the F/A-18 Hornet and introduce it into service was broken down into phases, which culminated in live firings at instrumented ranges in the US and Australia.

This paper includes details of the ADF aircraft stores separation clearance process and test program undertaken by the Aerospace Operational Support Group (AOSG) that has lead to the successful weapon system integration clearance and introduction into service of the AIM-132 ASRAAM with the RAAF. The paper also contains a summary of test results and how the developing capabilities such as the Aircraft Stores Compatibility Engineering Agency (ASCENG) Weapon Separation Analysis System (WSAS) and the Defence Science and Technology Organisation (DSTO) Hazards of Electromagnetic Radiation to Ordnance (HERO) test facilities were used to minimise certification costs and provide an eventual clearance envelope second to none off the F/A-18 aircraft.

The application of proven ADF risk mitigating strategies significantly reduced the cost of certification of the F/A-18 / ASRAAM configuration. The photometric analysis and simulation tool, WSAS, developed by ASCENG is a vital tool in the store clearance process, providing an excellent cost effective approach to aircraft store integration. Due to the complexity and cost of individual test assets, the development of modelling and simulation tools is crucial to the integration of future weapon systems.

1.0 INTRODUCTION

The Australian Government signed a contract with Matra British Aerospace Dynamics and Alenia Marconi Systems (MBDA) in November 1998 to equip the fleet of F/A-18 Hornet aircraft with the AIM-132 Advanced Short Range Air to Air Missile (ASRAAM), shown in Figure 1. The task of integrating testing and clearing ASRAAM onto the F/A-18 was shared between the United States Navy (USN) and the RAAF.

Initial USN planning for stores clearance of the ASRAAM on the F/A-18 called for a significant number of separation missiles (30 in total to cover all three firing configurations) - all with telemetry. Based on a limited project budget and the previous certification of the AIM-9M Sidewinder missile from these stations, the number of test assets was reduced by ASCENG to 13, with a mix of telemetry and Ballistic Non-Guided (BNG) rounds, including inert missiles for jettison.

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The USN was originally responsible for integrating ASRAAM into the F/A-18 15C Operational Flight Program (OFF). However, to flight test the OFF software they required a small firing envelope, from the wing tip station, and offered to provide that limited clearance to the RAAF. It was later agreed that the USN would provide the carriage and employment flight clearance envelope for ASRAAM on wingtip stations in the clean configuration, requiring 5 or 6 missiles with telemetry. The RAAF was therefore responsible for the remainder of the aircraft stores clearance, which included missile carriage and employment from wingtip and underwing stations for mixed loads to the aircraft design limit. It is important to note that ASRAAM will eventually be integrated with the Joint Helmet Mounted Cueing System (JHMCS), and hence in order to maximise the benefits of the JHMCS, the employment envelope had to be expanded to limits of basic airframe (LBA). With only 13 test assets available after re-costing, this left the RAAF (namely ARDU) with only 7 missile firings - initially without telemetry. Later agreements gave ARDU the grand total of 2 telemetry missiles as part of the 7. Based on an ASCENG engineers' previous experience of the separation clearance of ASRAAM from Tornado aircraft (& pre-flight simulations for Eurofighter Typhoon aircraft), it was decided that the required envelope for the underwing LAU-115 missile stations could still be met due to the benign separation characteristics of the missile. The clearance basis was to be achieved using mathematical modelling progressively validated by the limited flight test firings.

Figure 1: AIM-132 Advanced Short Range Air to Air Missile (fitted in the F-111 Bomb Bay)

A significant component of the F/A-18 / ASRAAM integration program was to conduct a Hazards of Electromagnetic Radiation to Ordnance (HERO) evaluation using the Electromagnetic Environment (EME) that the aircraft is expected to encounter in its training and operational service. HERO testing was conducted using DSTO’s aircraft sized reverberation chamber, an Open Area Test Site (OATS) and a revolutionary mini reverberation chamber. The HERO tests were extremely successful with the F/A-18 / ASRAAM configuration cleared for the Australian EME.

In support of the integration of ASRAAM onto the AF/A-18, the RAAF have also conducted a comprehensive Flutter Test Program. A thorough theoretical investigation of flutter onset speeds for a range of store configurations with wingtip ASRAAMs was conducted. Cross comparison of the results from flights with AIM-9 and ASRAAM verified that the differences between the missiles did not significantly change the flutter behaviour.

2.0 SYSTEMS ENGINEERING PROCESS

Systems engineering is an overarching discipline, providing the tradeoffs and integration between system elements to achieve the best overall product and/or service. It is known that the systems engineering process is basically an iterative process of deriving/defining requirements at each level of the system, beginning at the top (the system level) and propagating those requirements through a series of steps which eventually lead to a preferred system concept. Further iteration and design refinement leads successively to preliminary design, detail design, and finally approved design.

ASCENG has adopted a systems engineering approach towards conducting stores clearances. The aircraft/store combination is treated as a whole system, and the following areas analysed for each configuration:

a. Fit & Function,

b. Structural & Environmental,

c. Aeroelasticity,

d. Captive Compatibility, Flying Qualities & Performance,

e. Employment & Jettison, and

f. Ballistics and OFP Validation & Verification, Safe Escape & Safety Templates.

Each of the above areas forms a part of the Aircraft and Stores Compatibility Engineering Data Packages, and the data requirements for each section are at [1].

Two of the vital tools that a systems engineer requires are systems modeling across a broad range of engineering and programmatic disciplines, and risk management of all constituent elements of the system. Models and simulation of representative scenarios are one of the most significant and comprehensively used risk reduction tools available.

By using the systems engineering approach, risks can be identified early enough for meaningful changes to be made to the associated program/project. Further discussion on ASCENG's systems engineering processes is at [1] and [2].

3.0 HERO TEST PROGRAM

A significant component of the ASRAAM / F/A-18 integration program was to conduct a Hazards of Electromagnetic Radiation to Ordnance (HERO) evaluation using the Electromagnetic Environment (EME) that the aircraft is expected to encounter in its training and operational theatre. To facilitate certification of the missile for operational use the ASRAAM / F/A-18 combination was required to successfully complete HERO susceptibility testing to the Australian defined EME.

An F/A-18 ASRAAM Electromagnetic Environmental Effect (E^3) Working Group[1] was formed to assess the feasibility of conducting on aircraft ASRAAM HERO testing in Australia. In May 2001, based on the development of indigenous expertise and cost, the working group selected DSTO and ARDU, in collaboration with the Defence Evaluation and Research Agency (DERA) and the USN, to conduct the ASRAAM HERO testing at the DSTO Edinburgh facilities in South Australia. DSTO is leading the world with respect to the test technique and facilities that will be used to conduct this test which offers a significant enhancement in test efficiency and effectiveness.

[1] The F/A-18 ASRAAM Electromagnetic Environmental Effect (E^3) Working Group included personnel from ARDU, Directorate of Technical Airworthiness, AIR5400 Project Office and Tactical Fighter Systems Project Office (TFSPO)

A HERO Test Program of this magnitude had never been conducted in Australia previously, nor have some of the test techniques been used for HERO testing. International expertise from the US and UK were sought to provide assistance and independent advice to ensure HERO certification using world leading techniques. Significant contributions were also obtained from aircraft test authorities HERO experts and Reverberation Chamber experts.

3.1 Test Program Aims

The primary aim of the HERO test program was to achieve HERO certification of the ASRAAM operational and telemetry missiles from RAAF F/A-18 aircraft to the Australian defined F/A-18 EME.

The ASRAAM Contract specified MIL-STD-1818A as the compliance standard for EME. However the ADF preference was to achieve as many of the requirements of MIL-STD-464 that exceed MIL-STD-1818A as is possible within the funding constraints. DSTO further developed the EME to take into account the expected operational environment of the F/A-18 both within Australia and in expected areas of operation outside Australia. Hence the required EME actually exceeds MIL-STD-464 in certain areas.

The secondary aim of the HERO test program was to conduct limited E^3 base line tests in support of the Hornet Upgrade (HUG) Program and AIR5400 Project Office engineering activities. A limited number of systems were tested and included the armament computer, the flight control computer and the mission computer.

3.2 ASRAAM Test Article

The system under test was the ASRAAM Hazard Monitoring Equipment (HME) Missile fitted to a LAU-7/A-7 (AUS) missile launcher installed on the stations 1 and 9 and an ASRAAM HME missile fitted to a LAU-115 / LAU-127 missile launcher installed on stations 2 and 8 of a HUG AF/A-18A and AF/A-18B aircraft. The ASRAAM HME missile was used for the HERO testing, as it was physically and electrically representative of the ASRAAM operational missile with the exception of the removal and instrumentation of the missile electro-explosive devices (EEDs) and inerting of all other explosives.

3.3 Facilities and Test Techniques

All HERO testing was conducted at the DSTO Edinburgh site located next to RAAF Base Edinburgh, South Australia. The testing was conducted using a variety of facilities and test techniques. The majority of the HERO testing was accomplished using a Reverberation Chamber. The chamber is one of the largest in the world with nominal dimensions 21m x 11m x 6m and is illustrated in Figure 2. A description of the chamber's design, commissioning and characterisation is contained at [3]. Due to the size of the Reverberation Chamber relative to the F/A-18, the wings had to be folded so that the aircraft could be positioned in the chamber (refer Figure 3). There was initially considerable concern regarding the quality of test results with folded wings. However, testing revealed that there were no adverse effects associated with folded wings in the reverberation chamber and that results obtained were actually more reliable that those obtained using the Open Area Test Site (OATS).

Other facilities included the OATS (refer Figure 4) which used conventional HERO Testing techniques and the Mini - Chamber Test Facility (MCTF) (refer Figure 5). The MCTF allows high power to be provided at the range of frequencies of interest at a particular section of the aircraft. The Mini Reverberation Chamber technique incorporated was a world first and is regarded as a world-leading concept. The technique was so successful that it will be adopted internationally. It is anticipated that the MCTF technique will be used during a Eurofighter cockpit investigation.

The international HERO experts contributing to the HERO Testing were extremely impressed with the DSTO facilities and the manner in which the tests were conducted. They are quoted as saying that DSTO are *"leading the world with this type of testing"* and that the testing was *"as good if not better than anywhere else in the world"*.

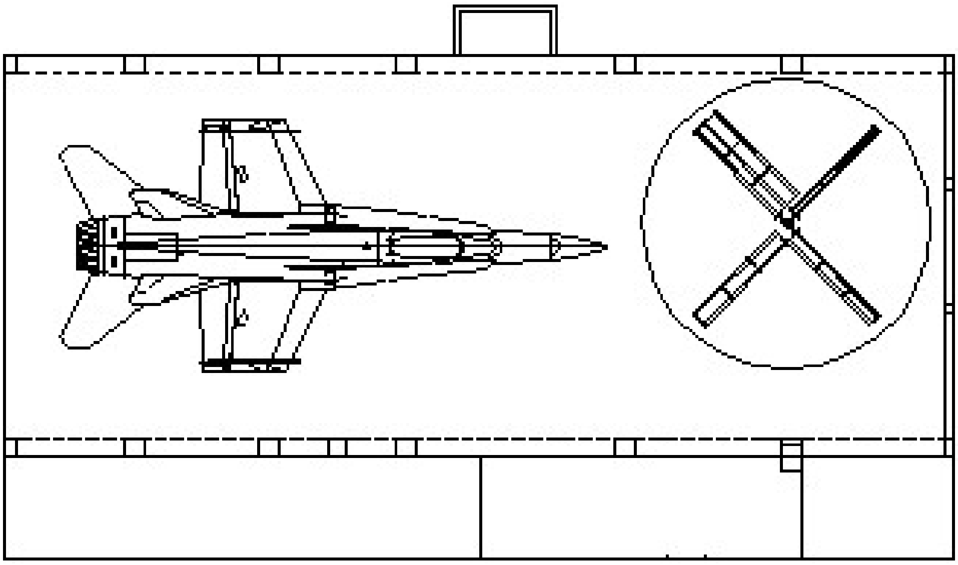

Figure 2: Plan View of F/A-18 in the DSTO Reverberation Chamber

3.3 HERO Test Results

Detailed discussion of the methods of test and results are contained in [4], and may be obtained on request via the Reports Distribution Officer, DSTO Research Library, Edinburgh, Australia.

Figure 3a: F/A-18 Positioned in the DSTO Reverberation Chamber (front view)

Figure 3b: F/A-18 Positioned in the DSTO Reverberation Chamber (rear view)

Figure 4: F/A-18 Located at the DSTO Open Area Test Site

Figure 5: Implementation of Mini - Chamber Test Facility (MCTF) on the OATS

4.0 FLUTTER TEST PROGRAM

The RAAF F/A-18 / ASRAAM Flutter Test Program has previously been presented at the International Test and Evaluation Association (ITEA) Aircraft-Stores Compatibility Symposium XII. Details of the RAAF Flutter Test Program are contained in [5]. A brief summary of the program is provided below.

A thorough theoretical investigation of flutter onset speeds for a range of store configurations with wingtip ASRAAMs was conducted. This analysis suggested a substantial reduction in the flutter onset speed with heavy stores on the outboard pylons. Since such analyses are generally conservative (i.e. under-predict the flutter speed), the decision was made to conduct flight flutter tests to confirm the accuracy of the predictions and determine the aircraft flutter onset speed more accurately.

The flutter flight test program was developed as a joint program between ASCENG, ARDU and DSTO. Both organisations had previous flutter test experience with the F-111C aircraft. Using this experience as a basis, a flutter test program was tailored specifically to the AF/A-18. Development of this program also drew on the extensive experience and lessons learnt by the Canadian Forces (CF) and USN.

The Australian ASRAAM flutter program was designed to investigate the low frequency vibration modes of the wing and stores. The predicted critical modes targeted for the investigation were antisymmetric wing first bending and antisymmetric outboard store pitch resulting in classical flutter at high dynamic pressure. Testing was conducted at subcritical airspeeds (i.e. below the flutter speed) in what were predicted to be the worst configurations, and the technique of Zimmerman and Weissenburger [6] used to predict the aircraft flutter speed. Testing was carried out at subsonic and supersonic speeds.

Desktop studies carried out by ASCENG prior to testing concluded that the missiles' mass and inertia properties were sufficiently similar to give/practically identical flutter speeds; the AIM-9 forward fins were judged to have an insignificant effect on the flutter speed. Cross comparison of the results from flights with AIM-9 and ASRAAM verified that the differences between the missiles did not significantly change the flutter behaviour.

5.0 STORES SEPARATION CLEARANCE PROCESS

The process envisioned for separation clearance of ASRAAM is illustrated in Figure 6 and consisted of progressive validation of a mathematical model, with the validated modelling results used as clearance evidence in conjunction with the limited flight test data points. This approach has been used for many years to great effect in Europe (in particular the UK where it is known as 'fly-match-fly') and recently in Israel [7]. From the outset, the number of flights required can be reduced, and as the program develops, the upcoming test points can be re-focussed to better meet the primary requirement of creating a comprehensive validated model. Often, the number of flight tests can be further reduced through the re-focussing effort. A further major benefit is the impact on future test requirements due to weapon changes. For example, a significant CofG change of a missile can be assessed using the validated model without recourse to flight test. This has a significant effect on the reduction of aircraft store certification costs.

The approach is not without its problems, as it can be difficult to tune a model to a new test point and maintain a model that is coherent with all previous tests. More modelling effort is involved and test schedules tend to get 'strung out' as adequate time for analysis is required between flights.

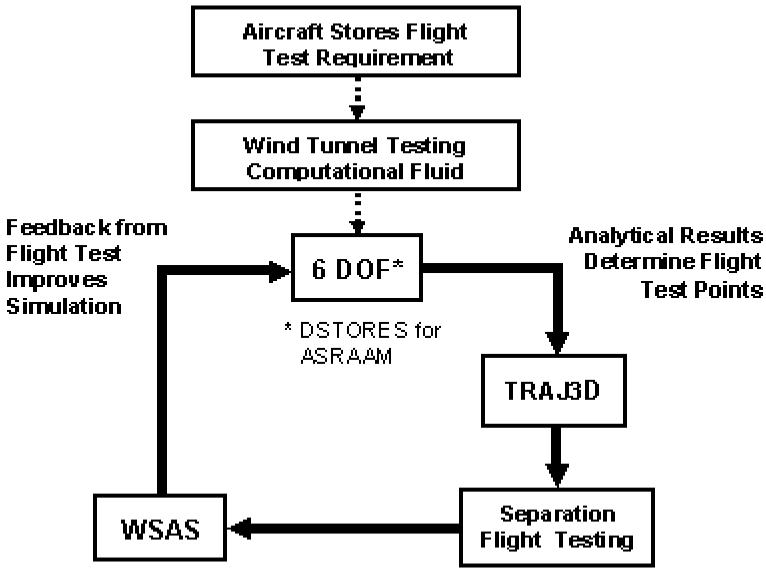

Figure 6: Separation Clearance Process

This store separation clearance process had not been attempted in Australia for forward firing stores for quite some time, and unfortunately, the development of the wind tunnel and modelling tools did not keep pace with the original ambitions. Luckily, prior experience with ASRAAM firings from UK aircraft suggested very benign separation characteristics. A more traditional approach to flight test could therefore be taken, namely flight test build up. However, with this in mind and the low number of test assets available, an aggressive 'corner point' test program was devised to not only provide sufficient evidence of acceptable behaviour from underwing, but also extend the wing tip envelope and validate the separation simulation code that was used to predict the safety of the devised release conditions. The separation behaviour was to be quantitatively measured using the new ASCENG Weapon Separation Analysis System (WSAS) capability. Pre-flight modelling, with generous safety factors were used to determine safety of flight for the tests. The aim was to produce a coherent model once all test points were completed.

5.1 Political and Capability Constraints

The approach to deriving a separation clearance for ASRAAM from the RAAF F/A-18 was unusual due to political and capability constraints. Political aspects included the wing tip test firings and clearances being mandated as being undertaken by the USN and the number of telemetry missiles available for use by ARDU was curtailed due to the limited budget.

Capability constraints were numerous and included:

a. the grid loads data required for underwing missiles were measured in a new DSTO transonic wind tunnel and were delayed by tunnel teething problems with the subcontractor

b. the separation simulation code was still under development and this was the first attempt at simulating a rail launch by DSTO; and

c. the photometric measurement capability, WSAS, was also in major re-development and it was not certain that photometrics could be used for a small forward firing missile given the limitations of camera coverage.

The potential for disaster to the project was further compounded by USN reports of AIM-9M and AIM-9X wing tip missile separation problems that would limit their ability to provide a wing tip separation envelope acceptable to the RAAF for the AF/A-18.

5.2 USN Involvement

USN testing of the ASRAAM missile on the F/A-18 aircraft for RAAF commenced in January 2000 at both China Lake, California and Patuxent River, Maryland. The scope of this testing was to validate the software integration of ASRAAM into the OFP 15C software load for the F/A-18 Hornet aircraft. Testing performed included lab testing of the complete system, flutter testing, captive carriage performance testing and separation testing. The USN program concluded with a live-firing of a ASRAAM Telemetry Missile at a USN supplied target in a complete end-to-end test.

Consistent with ADF policy, an experienced Aircraft Stores Compatibility Engineer was posted to the USN Patuxent River and China Lake sites for the duration of the project. This ensured good communications and a timely response to our questions, and was crucial in meeting project timescales for ARDU's test program, in particular with the supply of data to enable the high 'g' firings to proceed.

6.0 ASRAAM SEPARATION CLEARANCE PROGRAM

6.1 Weapon Separation Analysis System (WSAS)

WSAS is a software tool for analysing cine film (or video) footage of weapon separation events. The tool derives quantitative information on the position and orientation of a weapon for each film frame and so measures the trajectory relative to the aircraft. The system is capable of determining store three axis positions relative to the releasing aircraft to accuracies better than 0.1 metre, and store attitude (roll, pitch, yaw) to better than 0.5 degree. The tool uses an image matching process, where 3D models of aircraft and store are viewed using a synthetic camera with the models being manipulated by the user to overlay their corresponding film images that have been corrected for camera lens distortion effects (Figure 7). The current system is written entirely in Matlab™ and compiled to work on a PC.

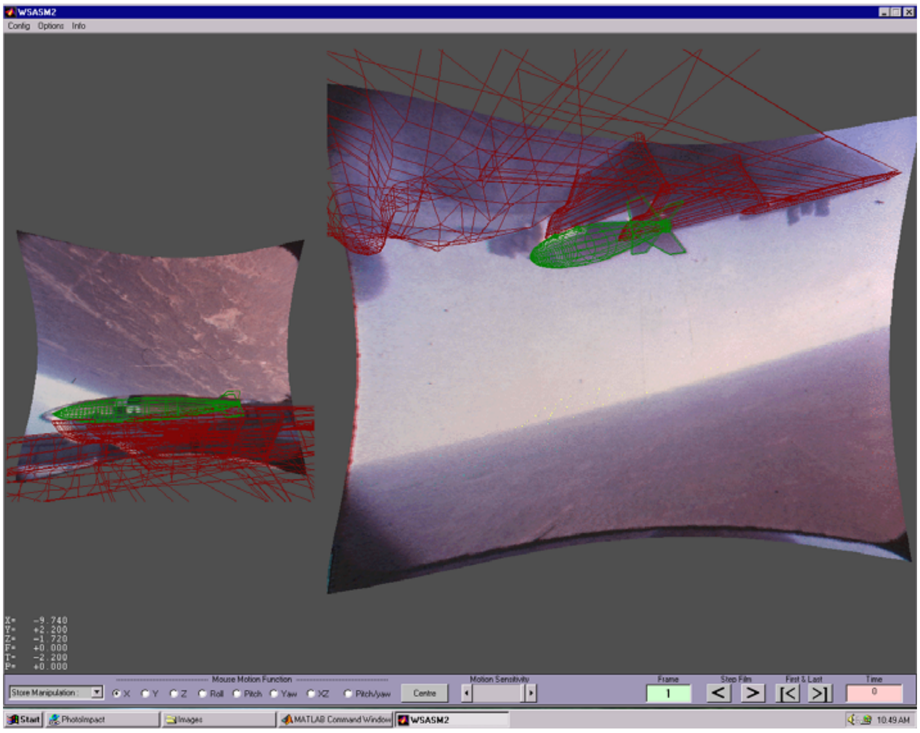

Figure 7: WSAS Screen Shot

Although manpower intensive, an analysis of two or three cameras for a separation event can be analysed within one day. Though not essential, it helps if both aircraft and weapon have clearly visible unambiguous markings accurately surveyed, and that any camera fitted to the aircraft can be supplied with timing information. Best accuracy is obtained when more than one camera station is employed, but useful results can be obtained from only one camera. Ideally three perpendicular cameras should be used looking from the rear, from the side and from the top onto the store. It is possible to get useful results by analysing film recorded by a chase aircraft (though of lesser accuracy). A major advantage of the image matching technique is the ability to use relatively poor film images if necessary.

Early in the ASRAAM integration project there was a question as to WSAS could provide the required trajectory information given the small missile size and limited camera views on the F/A-18 (which is why the USN had insisted on telemetry missiles for the wing tip).

A flight test firing of an AIM-9 missile as a test analysis for WSAS was therefore set up. It was found that a reasonable trajectory could be determined by using the cine film footage from the chase aircraft to supplement the onboard cameras. On the basis of this, good chase footage became an important deliverable of the ASRAAM flight testing.

6.2 Additional Background to Separation Testing

Given the limited number of firings available, the clearance process relied heavily on mathematical modelling. Unfortunately the DSTO six degrees-of-freedom (6DOF) separation model (DSTORES) was still being developed. In particular, a rail launch capability was being added for the very first time in Australia, and development was proving to be troublesome.

A further complication to the modelling effort was DSTO's new transonic wind tunnel. It had only just been completed, (two years behind the contractor’s schedule) and was having several teething problems[2].

[2] Teething problems culminated in the compressor exploding in 2001.

It was unknown as whether it was going to be available to provide data for mathematical modelling in time for the first flight.

In lieu of wind tunnel data, Computational Fluid Dynamics (CFD) using FLUENT Euler code was used to generate 'down the rail' grid loads for the 6DOF simulation. Considerable experience had been gained in the method by DSTO, to give some confidence in the data. In fact DSTO had done extremely well using Fluent in the CFD Challenge 2 [8]. Significant aerodynamic tolerances were applied to the simulations to show that there were no major separation concerns.

Initial missile firings were successful and cine film showed benign separations. The quantitative trajectory time histories produced by WSAS confirmed the initial impressions from the film. Comparison of the WSAS measured time histories with predictions was not good[3] but within the considerable tolerance bands.

6.3 ASRAAM High 'g' Firing

The USN wing tip firing tests were also progressing well initially, then came news of 'serious separation problems' after the mid 'g' wing tip firing by USN. The missile rear hanger was damaging the last few inches of the launch rail (refer Figure 8). The USN considered that this was of great concern and would require extra missiles to expand the clearance - if any expansion was possible.

Figure 8: Rail 'Gouging' of the LAU-7 Launcher

ASCENG was puzzled, as the RAAF had not had any problems with their underwing mid 'g' firing from LAU-127 and there were no problems with even high 'g' launch from the UK Tornado. ASCENG postulated that this was probably due to the very difficult flow conditions experienced round a wing tip launcher, causing the missile to 'roll' the hanger into the rail.

The initial postulation that the wing tip launcher 'gouging' was aerodynamically driven by flow around the wing tip meant that the problem should have been seen for AIM-9 and that the latter with large rear fins should in fact be worse than the ASRAAM. Requests for information from the USN revealed that recent AIM -9 wing tip firings had indeed experienced launcher gouging.

[3] Coding errors in DSTORES have since been found & corrected.

Also, the telemetry data from the USN mid 'g' firing became available and showed insignificant effects on the overall trajectory attributable to the gouging. Studies by MBDA on the missile, hanger and launcher operating under such conditions showed that the strength was more than adequate. On this basis ARDU went ahead with their underwing maximum 'g' firing and again showed no problems.

Photographic comparisons of the rail gouging marks caused by ASRAAM and AIM-9 at the same mid 'g' condition revealed little difference, when one would reasonably have expected deeper gouges from the AIM-9. This lead to the realisation that the damage was more likely to be due to the effective weight of the missile under 'g', bearing down on the rail through the last hanger. The hanger is hard steel, and the rail soft aluminium with force applied on the lower sidewall due to the orientation of the LAU-7 on the wing tip - a condition for which the LAU-7 was not originally designed.

At this point, several questions were raised. Why was this not noticed for AIM-9 earlier? What about AIM-9 at max 'g'? Were there any reports of damage from operational usage? What about wing tip missiles on other aircraft, ie F-16?

It was surprising to find that **NO** test firings of AIM-9 were conducted at these typical combat conditions until recently. No data is available for operational use or other aircraft problems. The disturbing conclusion was therefore made that wing tip AIM-9 has been in service on F/A-18 for over 20 years without adequate separation testing.

The wing tip ASRAAM max 'g' test was conducted in Australia and as expected, rail gouging was observed. The rail gouging was consistent with the proportional increase in 'g' compared to the previous firing. The separation was otherwise entirely satisfactory.

Based on a formal risk assessment, ASCENG saw no reason to limit the separation envelope, though the rail should be monitored after mid to high 'g' firings and is obviously an issue for maintenance and logistics support, but then so is AIM-9 and probably other air-to-air missiles.

6.4 ASRAAM Extreme Alpha Firing

Another highlight of the RAAF testing is the high incidence test firing. Although the wing tip firing by the USN at 30 alpha is operationally sufficient for the current F/A-18, it was essential to aim for an unlimited missile launch envelope - LBA for use with JHMCS. To this end, a further step towards this objective was taken by firing a missile at 45 alpha - albeit at very low speed. This is believed to be a world first.

The chase aircraft cine views proved extremely useful for WSAS analysis and resulted in good time histories. Again the comparison with the DSTORES prediction was poor, ultimately leading to the development of an ASCENG separation 6DOF model in Matlab™ / Simulink™ - referred to as STEME [9]. In combination with the USN data this firing provides an excellent basis for extrapolation to the full aircraft incidence capability.

6.5 Jettison of Missile Launcher Assembly

The jettison testing of the missile launcher assembly (MLA) also pushed the boundaries of photometric analysis and simulation. Whereas jettison of the MLA with the AIM-120 AMRAAM or AIM-9 is not cleared for an asymmetrically loaded single missile, it was desirable for ASRAAM for the RAAF operational requirement.

CFD was also used as the data source for the jettison simulations of the MLA which consisted of the LAU-115 + 2 * LAU-127 with 1 or 2 missiles. In this case there was historical wind tunnel and flight test data available for the MLA with AMRAAM and this was used as validation for the CFD and 6DOF simulation jettison modelling. Comparisons with the AMRAAM test data were very encouraging. A graphical representation of the simulated jettison of the MLA in the asymmetric configuration is shown in Figure 9.

Figure 9: Simulated Jettison of the MLA in the Asymmetric Configuration

A flight test jettison of MLA with 2 missiles (symmetric) was conducted. The separation was clean, with a slow pitch down of the MLA and little roll or yaw. Although similar in trend to the DSTORES simulation, the latter over predicted the pitch down. This was primarily attributed to the ejection rack performance.

Detailed CFD studies by DSTO showed that an asymmetric jettison should be safe even though multi-axis tumbling would be present. An asymmetric MLA jettison flight test was conducted resulting in a spectacular separation which was entirely safe and largely as expected. Subsequent WSAS analysis proved to be relatively quick and easy with the chase cine film yet again giving invaluable input. This has provided useful validation data for mathematical modelling of multi-axis tumbling.

6.6 OFP Validation and Verification & Live Firings

The USN provided the initial validation of the software integration of the prototype ASRAAM into the OFP 15C software load for the F/A-18 Hornet aircraft. Subsequent to this, ARDU has been conducting an extensive OFP validation and verification program with the final ASRAAM variant, with particular attention to Mission Computer (MC) and Store Management System (SMS) updates. Numerous functionality tests were conducted to evaluate the OFP with ASRAAM to improve the human factors with the extant F/A-18 OFP. The OFP passed all necessary tests and met all acceptance criteria.

The integration program of the ASRAAM onto the F/A-18 Hornet Aircraft will culminate with Acceptance Test and Evaluation (AT&E) of the weapon system and successful end-to-end test firings of Telemetry and Operational Missiles against target drones. The comprehensive F/A-18 / ASRAAM integration program, with the confidence gained from the use of weapon separation analysis tools, provided an excellent lead-up to these firings. The acceptance testing involved both captive carriage testing and live firings of ASRAAM missiles to evaluate the Infra-Red Counter-Counter-Measure (IRCCM) performance and the missile's kinematic ability to engage targets from high alpha look down scenarios and high off-boresight angles. Results of the ASRAAM testing and performance of the weapon system are classified and therefore will not be discussed in this paper. However, it can be stated that testing demonstrated excellent potential and represented a significant capability improvement over the AIM-9.

7.0 CONCLUSION

The ADF aircraft stores clearance process has been shown to minimise the number of test articles used during a test program and consequently significantly reduce the aircraft store certification costs.

The clearance process utilises the ASCENG developed WSAS tools together with DSTO wind tunnel and CFD results. It was noted that good chase footage became an important deliverable of the ASRAAM flight testing enabling quick and reliable processing of results.

As with the majority of flight test programs, the F/A-18 ASRAAM separation clearance program was not without its problems. However, these problems were eventually overcome and significant highlights were achieved, namely:

a. a max "g" ASRAAM wing tip firing being successfully conducted;

b. an ASRAAM wing tip firing at 45 alpha being successfully conducted; and

c. the successful jettison of the MLA in an asymmetric configuration.

A comprehensive HERO Test Program was successfully completed using new and innovative testing techniques. Testing was conducted using a variety of DSTO facilities and test techniques including Reverberation Chambers and the OATS. The HERO tests were of considerable benefit to Australia and the ADF community, and have proven that Australia has an invaluable indigenous capability for conducting HERO testing, highlighting DSTO as a world leader in Reverberation Chamber testing. Of primary significance to the RAAF was that HERO certification of the ASRAAM operational and telemetry missile from F/A-18 aircraft to the defined Australian EME was successfully achieved.

The application of proven ADF risk mitigating strategies significantly reduced the cost of certification of the F/A-18 / ASRAAM configuration. The photometric analysis and simulation tool, WSAS, developed by ASCENG is a vital tool in the store clearance process, providing an excellent cost effective approach to aircraft store integration. Due to the complexity and cost of individual test assets, the development of modelling and simulation tools is crucial to the integration of future weapon systems.

8.0 ACKNOWLEDGMENTS

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ANNEX

A. Abbreviations and Definitions

9.0 REFERENCES

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Annex A

ABBREVIATIONS AND DEFINITIONS

6DOF. Six degrees-of-freedom

ADF. Australian Defence Force

AT&E. Acceptance Test and Evaluation

Aircraft Store. Any device intended for internal or external carriage and mounted on aircraft suspension and release equipment, whether or not the item is intended to be separated in flight from the aircraft.

Aircraft Stores Capability. The capability provided by specified aircraft stores configuration(s) certified as meeting approved operational suitability, effectiveness and preparedness criteria.

Aircraft Stores Certification. An engineering, operational and logistics activity that results in the documentation by the Technical Airworthiness Regulators Design Acceptance Representative (DAR) and Operational Airworthiness Authority Representative (OAAR) or delegate that specified aircraft stores configuration(s) in the Aircraft Stores Compatibility Clearance are operationally suitable, effective and that the preparedness status of the established integrated logistics support meets the endorsed Operational Requirements for the aircraft stores capability. Formal approval for the authorisation and Release to Service of an aircraft stores configuration is accomplished through publication of appropriate technical orders and manuals.

Aircraft Stores Clearance. Primarily a systems engineering activity that results in the documentation of the extent of aircraft stores compatibility to safely prepare, load, carry, employ and/or jettison specific aircraft stores configurations within the specified ground and flight operating envelopes.

Aircraft Stores Compatibility. The ability of each element of the specified aircraft stores configuration(s) to coexist without unacceptable effects on the physical, aerodynamic, structural, electrical, electromagnetic or functional characteristics of each of the other under specified ground and flight conditions.

Aircraft Stores Compatibility Clearance. A document, issued by ASCENG that defines the extent of aircraft stores compatibility to safely prepare, load, carry, employ and/or jettison specific aircraft stores configurations within the specified ground and flight operating envelopes.

Aircraft Stores Configuration. An aircraft stores configuration refers to an aerospace platform, incorporating a stores management system(s), combined with specific suspension equipment and aircraft store(s) loaded on the aircraft in a specified pattern. An aircraft stores configuration also includes any downloads from that specified pattern resulting from the release of the store(s) in an authorised employment or jettison sequence(s).

AMRAAM. Advanced Medium Range Air to Air Missile

AOC. Active Oscillation Control

AOSG. Aerospace Operational Support Group

ARDU. Aircraft Research and Development Unit. The Air Force unit responsible for planning, conducting and reporting Air Force and Army aerospace T&E.

ASCENG. Aircraft Stores Compatibility Engineering Agency. The tri-service agency reporting to Air Force responsible for airworthiness and suitability standards, planning, conducting, approving and supporting operations for all ADF state aircraft stores configurations.

ASRAAM. Advanced Short Range Air to Air Missile

BNG. Ballistic Non-Guided

CofG. Centre of Gravity

CF. Canadian Forces

CFD. Computational Fluid Dynamics

DERA. Defence Evaluation and Research Agency – UK

DSTO. Defence Science and Technology Organisation

DSTORES. DSTO Release Evaluation Suite

EEDs. Electro-explosive Devices

E^3. Electromagnetic Environmental Effect

EME. Electromagnetic Environment

EO. Explosive Ordnance

HERO. Hazards of Electromagnetic Radiation to Ordnance

HME. Hazard Monitoring Equipment

HUG. Hornet Upgrade

IIR. Imaging Infra-Red

IRCCM. Infra-Red Counter-Counter-Measure

ITEA. International Test and Evaluation Association

JHMCS. Joint Helmet Mounted Cueing System

LBA. Limits of Basic Airframe

M. Mach Number

MBDA. Matra British Aerospace Dynamics and Alenia Marconi Systems

MC. Mission Computer

MLA. Missile Launcher Assembly

NAWC. Naval Air Weapons Center

OATS. Open Area Test Site

OFP. Operational Flight Program

RAAF. Royal Australian Air Force

SMS. Store Management System

STEME. Store Trajectory Estimation in a Matlab™ Environment

TAB. Technical Airworthiness Bulletin

T&E - Test and Evaluation. Test and Evaluation is the measurement of the performance of a system, and the assessment of the results for one or more specific purposes. T&E is usually conducted to assist in making engineering programmatic or process decisions, and to reduce the risks associated with the outcome of those decisions.

TFSPO. Tactical Fighter Systems Project Office

UK. United Kingdom

USA. United States of America

USN. United States Navy

WSAS. Weapon Separation Analysis System

DISCUSSION EDITING

Paper No. 6: Integration F/A-18 / AIM-132 ASRAAM Integration, Test and Clearance Program

Authors: David A. Pierens

Speaker: Malcolm Tutty.

Discussor: Franco Moretti

Question: Did you use wind tunnel data to set up the mathematical models for the ASRAAM and for the launcher jettison on F/A-18?

Speaker's Reply: The launcher jettison was modelled using CFD but wind tunnel grid loads were used for ASRAAM firing models.

Discussor: Jean Philippe Planas

Question: Wing tips firing limited to 4 g´s?

Is it for A/C safety purposes of rail fatigue life?

Speaker's Reply: The RAAF successfully conducted M&S and flight testing to Limits of the F/A-18 aircraft for "G" and Angle of Attack". The limiting to 4 "G" is for logistic purposes to reduce cost of repairing and/or replacing launch rails during peacetime training. The testing was conducted to higher "G" and AoA to ensure that wartime firings at such higher values was safe and suitable when the rather small repair costs would be more than acceptable if a kill was to be made. One should note that most test and/or training ranges are not set-up to conduct such high "G" or AoA firings as a matter of course due to the extremely large safety templates that are required. As you'll recall in the presentation, the ASRAAM can be carried and fired anywhere the F/A-18 can fly in controlled flight which is an unprecedented capability.

Discussor: Alex Cenko, NAVAIR

Question: Did you model the autopilot in your simulation and, if so, did you have problems getting the autopilot parameters from the missile manufacturer?

Speaker's Reply: Yes Alex it most certainly was. In the case of the ASRAAM the "autopilot" is locked out for a period of time so that the missile is headed directly ahead for safe separation before the missile is able to start guiding. The Autopilot parameters are included in the Stores Compatibility Engineering data Package provided iaw AAP 7001.067 ADF Air Armament Manual (and is covered to a lesser extent by MIL-HDBK-1763 Appendix C). Yes we initially have challenges in this data being provided, however, the delivery of such information is imbedded in the Contract in two or three places which makes it very hard for the Contractor to avoid its provision. In any case if such data is not provided that is also not support by a systems safety assessment, it does not fly until it is, QED. Even the marketers can understand this position. Today we are getting these parameters supplied in MATLAB & Simulink format which makes such analyses a lot easier - as will be discussed in Mr Akroyds Paper 17 later in the Conference on Australia's Stores Trajectory Estimation in a MATLAB Environment (STEME) system.